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ABSTRACT

A working group of the Commission for Agricultural Meteorology has prepared this report to fill a need for detailed syllabi for instruction in agricultural meteorology required by different levels of personnel. Agrometeorological personnel are classified in three categories: (1) professional meteorological personnel (graduates with basic training in meteorology); (2) agricultural scientists (graduates with basic training in agricultural sciences); and (3) technical assistants in agrometeorological services (non-graduates, with training in mathematics and physics at the secondary or high school level). Proposed qualifications and training of these three classes of personnel are detailed, indicating the standard of knowledge required and the extent of the field to be covered. In addition, a syllabus is developed for teaching agricultural meteorology at secondary schools (advanced education below university degree level) of agriculture, horticulture, and forestry. It consists of a number of lectures and practical exercises to be introduced into the program of such schools. The list of textbooks and published lecture notes or monographs is compiled alphabetically by author with special listings of technical publications and World Meteorological Organization publications. (BL)

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SYLLABI FOR INSTRUCTION IN AGRICULTURAL METEOROLOGY

Report of a working group of the Commission for Agricultural Meteorology

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WMO - No. 202. TP. 106

Secretariat of the World Meteorological Organization - Geneva - Switzerland

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NOTE

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WORLD METEOROLOGICAL ORGANIZATION

SYLLABI FOR INSTRUCTION IN AGRICULTURAL METEOROLOGY

Report of the CAgM Working Group on Syllabi for Instruction in Agricultural Meteorology
prepared by
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FOREWORD

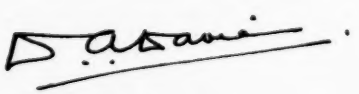
Recognizing the need for detailed syllabi for instruction in agricultural meteorology and for guidance with respect to appropriate textbooks, the WMO Commission for Agricultural Meteorology (CAgM), at its third session (Toronto, 1962), decided to establish a Working Group on Syllabi for Instruction in Agricultural Meteorology. This group was requested to prepare syllabi suitable for the different levels of personnel and to propose a list of appropriate textbooks, published lectures and monographs.

The group consisted of Messrs. G. D. B. de Villiers (South Africa), chairman, R. Arléry (France), J. van Eimern (Federal Republic of Germany), K. M. King (Canada) and Mrs. Z. Pieślak (Poland).

The final report of the group was circulated to all members of the commission for their information and comments and subsequently approved by the president of this commission. In view of the importance of its content, the president of CAgM recommended that the report be published in a suitable manner. The report has accordingly been included in the series of WMO publications intended for training purposes. It is expected that the French version will be published at a later date.

It may be appropriate to mention that the report of Professor J. Van Mieghem -- published as WMO Technical Note No. 50 entitled The Problem of the Professional Training of Meteorological Personnel of all Grades in the Less-developed Countries -- constitutes a basic reference to the present publication. Moreover, sections of the syllabi contained here will need to be completed by the relevant excerpts from Professor Van Mieghem's report.

I should like to take this opportunity of expressing to the chairman and all the members of the working group the sincere appreciation of the World Meteorological Organization for the time and effort they have devoted to the preparation of this very valuable report which will no doubt be of great assistance to all concerned with training in agricultural meteorology. I also wish to acknowledge with gratitude the assistance of Mr. L. P. Smith, president of CAgM, and of members of CAgM who have offered useful suggestions for the preparation of the final text.



(D. A. Davies)
Secretary-General

SYLLABI FOR INSTRUCTION IN AGRICULTURAL METEOROLOGY

1. INTRODUCTION

The syllabi presented in the following pages are based on a study of the desirable qualifications and training of personnel employed in agricultural meteorology.

2. CLASSIFICATION OF PERSONNEL EMPLOYED IN AGRICULTURAL METEOROLOGY

It was agreed that personnel employed in agricultural meteorology can be classified into two main classes:

Personnel with a basic training in meteorology;

Personnel with a basic training in agricultural sciences.

In each of these two classes distinction should further be made between graduate and non-graduate personnel.

When preparing syllabi for the various classes of personnel, the working group distinguished the following groups of personnel:

(a) Professional meteorological personnel (graduates with basic training in meteorology);

(b) Agricultural scientists (graduates with basic training in agricultural sciences);

(c) Technical assistants in agrometeorological services (non-graduates, with training in mathematics and physics at the secondary- or high-school level).

3. DUTIES OF THE VARIOUS GROUPS OF AGROMETEOROLOGICAL PERSONNEL

As regards the duties of the various groups of agrometeorological personnel, the working group considered that professional agrometeorological personnel and agricultural scientists were responsible for the organization and supervision of agrometeorological services and would carry out research in agricultural meteorology.

4. Technical assistants in agricultural meteorology would be responsible for the following duties: agrometeorological observations (instrumental, visual, phenological); installation, maintenance, checking and calibration of the instruments used, with the exception of very delicate instruments the adjustments of which should be entrusted to the professional officers; elementary processing of agrometeorological data: routine computation of averages, normals, frequencies, etc.; preparation of punched cards; statistical analysis of agrometeorological data under guidance of the professional officers; assisting in research projects.

5. SYLLABI

In the following pages the proposed qualifications and training of these classes of personnel are shown in the form of syllabi indicating the standard of knowledge required

and the extent of the field to be covered. The working group agreed that syllabi should be prepared for the three classes of personnel mentioned in paragraph 2 above, and that an additional syllabus was required for the purpose of teaching agricultural meteorology in secondary schools of agriculture, horticulture and forestry. Further details are given in the following paragraphs.

6. SYLLABUS FOR PROFESSIONAL METEOROLOGICAL PERSONNEL

Syllabus I, proposed for candidates in this class of personnel, is given in Annex I. For this syllabus the candidate must attain (or have attained) the required standard of knowledge in physics, mathematics, meteorology and climatology, and have sufficient background in the biological and agricultural sciences (if he has not already taken a degree in agriculture).

7. It should be possible to take this syllabus:

(a) As part(s) of a four-year B.Sc.Agric. course in agrometeorology;

(b) During postgraduate work in agricultural meteorology after a degree in pure science;

(c) During postgraduate work after a degree in agricultural science.

8. While instruction in biometry, botany (including plant physiology), crop science and soil science is considered essential for this course in agricultural meteorology, a knowledge of animal science, entomology and plant pathology may, under certain circumstances, also be desirable.

9. The proposed Syllabus I must be considered as the minimum requirement for the training of professional agrometeorologists. As regards personnel of Meteorological Services engaged in advisory tasks in agrometeorology, they should receive training in applicable parts of Syllabus I.

10. SYLLABUS FOR AGRICULTURAL SCIENTISTS

Syllabus II proposed for candidates in this class is given in Annex II. A one-year course in agricultural meteorology is proposed here for candidates who receive (or have received) training in agricultural sciences. The purpose of the proposed course is to make the agricultural scientist (student or graduate) more conscious of weather and climate and to train him in measuring meteorological and climatic influences when the need may arise in future research.

11. The standard of mathematics and physics required will be that of a first-year course at university.

12. If the postgraduate work of the agricultural graduate leans towards agricultural meteorology in animal, crop and soil studies, he may receive training in appropriate parts of Syllabus I for professional agrometeorological personnel.

13. SYLLABUS FOR TECHNICAL ASSISTANTS IN AGROMETEOROLOGICAL SERVICES

Syllabus III proposed for this class of personnel is reproduced in Annex III. The standard of mathematics and physics required will be that of the secondary or high-school level.

14. SYLLABUS FOR TEACHING AGRICULTURAL METEOROLOGY AT SECONDARY SCHOOLS OF AGRICULTURE, HORTICULTURE AND FORESTRY (The word "secondary" in this context implies advanced education below university degree level)

Syllabus IV proposed for the purpose of teaching agricultural meteorology at secondary schools of agriculture, horticulture and forestry is given in Annex IV. This syllabus consists of a number of lectures and practical exercises to be introduced in the programmes given at the professional secondary schools.

15. The purpose of introducing these lectures and exercises into the programmes of secondary schools of agriculture, horticulture and forestry is twofold:

(a) To avoid elementary meteorology being taught at universities and thus permit them to use the time gained for training in agricultural meteorology;

(b) To prepare a certain number of suitable observers for agrometeorological stations.

16. LIST OF TEXTBOOKS AND PUBLISHED LECTURE NOTES OR MONOGRAPHS

In accordance with its terms of reference, the working group prepared a list of textbooks and published lecture notes or monographs pertaining to instruction in agricultural meteorology. This list is reproduced in Annex V.

17. The works listed are arranged in alphabetical order of the names of the authors. Outstanding works which may be considered as reference books are marked with an asterisk (*) placed before the name of the author. Bibliographies of agricultural meteorology are given separately at the end of the list.

18. When preparing the list of textbooks, the group complied with the following guiding principles. Only works of a general nature were listed. As far as possible at least one such work was given for each language or group of languages. If two works in the same language were of similar nature and equal value, only the most recent work was listed. Works dealing with too restrictive or specialized subjects were not included. Whenever a relevant Technical Note existed, the title of this Note was inserted excluding all other works on the same subject. An attempt was made to include the most recent works; older works having an historical value were mentioned only in a few cases. Nevertheless this bibliography cannot be regarded as complete, and newer publications are constantly becoming available.

ANNEX I

SYLLABUS I

Syllabus for professional meteorological personnel

1. BASIC KNOWLEDGE REQUIREMENTS

1.1 Mathematics and physical sciences

1.1.1 Mathematics including statistics

See Professor J. Van Mieghem's report, WMO Technical Note No. 50, Annex II (p. 39).

1.1.2 Mechanics

See Professor J. Van Mieghem's report, WMO Technical Note No. 50, Annex II (p. 42).

1.1.3 Physics

See Professor J. Van Mieghem's report, WMO Technical Note No. 50, Annex II (p. 42).

1.2 Biological sciences

1.2.1 Biometry

Application of statistics to planning and analysis of experiments (see WMO Technical Note No. 50, Annex II (p. 41).

1.2.2 Soil science

Composition and formation of soils; weathering of rocks and minerals; the soil profile; simple classification of soils; plant nutrition and soil fertility; organic matter in soils; micro-organisms; the physical and chemical properties of soil; soil and plant relationships; soil erosion: types, causes; principles of soil conservation.

1.2.3 Botany

The morphology, anatomy and histology of flowering plants; systematic classification of plants; life-histories and reproduction of the more important plants; economic botany.

Plant physiology

The plant cell; solutions and membranes; the roots of plants; the intake of water and solutes by plants; the loss of water by plants; the processes of photosynthesis, including CO_2 requirements, respiration and growth in plants; the translocation of water and materials in plants; frost and drought hardiness; photoperiodicity.

Ecology

Plant association, successions and climaxes.

1.2.4 Crop production and management

1.2.4.1 Field crops

Physiographic, climatic, edaphic and biotic factors in relation to plant growth; crop production in relation to the agro-ecological conditions of the country concerned; agronomic practices; crop and fodder production; land utilization and industrial crops.

1.2.4.2 Horticultural crops

Classification of horticultural plants; climatic and soil requirements; elementary morphology and physiology; propagation; pruning; orchard layout and culture.

1.2.4.3 Pastures

The origin, development and stabilization of vegetation in relation to the environment; vegetation types, their management and application in veld management; the establishment and management of cultivated pastures.

1.2.5 Plant pathology

Importance of plant diseases; causes and classification; diseases caused by parasitic bacteria and fungi, viruses and non-parasites; influence of environmental factors on diseases of economic plants; principles of plant disease control.

1.2.6 Zoology

The elements of anatomy, histology and physiology; distinguishing characteristics of the major groups of the animal kingdom; a knowledge of the morphology, physiology and reproduction of representative types; elementary cytology, embryology and genetics.

Animal anatomy and physiology

The form, structure and functions of the locomotory, nervous, circulatory, respiratory, digestive, excretory, endocrine and reproductive systems of farm animals.

1.2.7 Animal husbandry and diseases of livestock

The principles of animal production; the nutrition of farm animals; physiological reaction to environmental changes in relation to food utilization; ecology of livestock; factors influencing growth and development; important animal diseases.

1.2.8 Entomology

Embryology, histology, physiology, ecology and the chemical, biological or other methods of control of the more important insect pests injurious to vegetables, fruit trees, field crops and pastures, stored grain and grain products, forests.

1.3 Meteorology (Physical, dynamic and synoptic)

See Professor J. Van Mieghem's report, WMO Technical Note No. 50, Annex II (pp. 42-43).

1.4 Climatology

The concept of climate; the influence of large-scale geographical factors such as ocean currents and the distribution of land masses and seas on climate; study of the general circulation from a climatological point of view; precipitation: convective rain, orographic rain, cyclonic rain, the diurnal variation of

precipitation, meridional distribution of precipitation, the seasonal variation of precipitation, viz. the equatorial type, the tropical type, the subtropical type, the continental type, the maritime type, the monsoon type; other climatic elements: sunshine, temperature, cloudiness, evaporation, humidity, radiation -- their diurnal and annual variations, their geographical distribution; classification of climates; global study of world climate; detailed study of the climate of the region or continent concerned; climatic changes; the utilization of climograms and phytoclimograms; the statistical manipulation of climate data on an advanced level.

2. AGRICULTURAL METEOROLOGY

2.1 Introduction

2.1.1 The importance of weather and climate for agricultural production

The adaptation of plants, crops and animals to the climate; the necessity of adjusting farming systems to the natural environment; critical growth periods in relation to temperature and soil moisture; the importance of weather and climatic data in determining the irrigation requirements of crops; climate in relation to insect pests and plant diseases; production and cultivation practices in relation to climate; climatic hazards affecting agricultural output, e.g. drought, hail, frost, strong wind, etc.; effects of climate and weather upon storage and transportation.

2.1.2 Agricultural meteorology

Definition, aims and scope; difference between meteorology and agricultural meteorology; a short history of agricultural meteorology in relation to the needs of agriculture and the development of meteorological apparatus.

2.1.3 National Meteorological Services and the World Meteorological Organization (WMO).

2.1.4 National agrometeorological organizations and the Commission for Agricultural Meteorology (CAgM).

2.2 Agrometeorological observations, instruments, stations, networks, and processing of data

2.2.1 Agrometeorological observations

2.2.1.1 Meteorological observations

Units, accuracy required, sources of errors, exposure of instruments, general rules and procedures for the observation and recording of pressure, air temperature, atmospheric humidity, wind, sunshine and radiation, precipitation, soil temperature, soil moisture content and soil moisture tension, evaporation, evapotranspiration, interpretation and analysis of autographic charts; cloud classification, cloud cover, estimation of cloud base; horizontal visibility; existing weather conditions; state of the ground.

2.2.1.2 Biological observations

Observations on native plants, cultivated crops and trees, farm animals, diseases, insect pests and general activities on the land.

2.2.2 Instruments and methods of observation

The choice of a site for an instrument enclosure; a detailed study of the procedures for installation, maintenance, checking and calibration of the instruments used in agricultural meteorology.

2.2.2.1 Pressure

The mercury barometer: method of observation, exposure, transportation and installation; correction of barometer readings to standard conditions: index error, gravity correction, temperature correction; the barograph, the aneroid barometer; the hypsometer.

2.2.2.2 Surface wind

The pressure plate anemometer; cup and fan anemometers: the hand anemometer, the totalizing anemometer, contact and generator types of anemometer and anemograph; the pressure tube anemograph; the hot-wire anemometer; etc.

2.2.2.3 Duration of sunshine

Sunshine recorders; exposure, maintenance and evaluation of records.

2.2.2.4 Radiation

Pyrheliometers, solarimeters, pyranometers, pyrradiometers, net radiometers, illuminometers and devices for measuring the spectral distribution of solar radiation. Instruments designed for use within crop canopies.

2.2.2.4.1 Estimates of radiation using sunshine, cloudiness and haze data.

2.2.2.5 Temperature

Liquid-in-glass thermometers: ordinary thermometers, maximum thermometers, minimum thermometers, soil thermometers; reading a thermometer; electrical thermometers: resistance thermometers, thermocouples, thermistors, auxiliary electrical equipment; thermographs: bimetallic type, Bourdon-tube type, mercury-in-steel type; thermometer and thermograph exposure: general requirements in order to obtain representative air temperature, thermometer screens, artificial ventilation, exposure of grass minimum thermometers; the importance of calibration certificates; possible sources of defects in thermometers and the various procedures to rectify them.

2.2.2.6 Atmospheric humidity

Psychrometers: simple psychrometer without artificial ventilation, the sling psychrometer, the Assmann-type psychrometer, exposure and observational procedure, care of the wet bulb, operation of wet bulb below freezing, sources of error in psychrometry, the psychrometric formula, tables and slide rules; hair hygrographs: general requirements, exposure, management and transportation, accuracy and sources of errors, washing the hairs; dew-point and frost-point hygrometers; electrical absorption-type hygrometers.

2.2.2.7 Precipitation

The ordinary and totalizing raingauges; rainfall recorders: natural siphon type, float type, tilting-bucket type, weighing type; rainfall intensity recorders; snow measurements: snow depth and density; the measurement of rainfall and hail by radar.

2.2.2.8 Dew

Artificial grass mats and asbestos plates; Parchinger's absorption method; the Leick porcelain plate; the paper-strip dew indicator; the Hiltner dew recorder; the Kessler dew recorder; the dew balance of Monteith; leaf-wetness recorders.

2.2.2.9 Soil moisture

2.2.2.9.1 Soil moisture content: electrical resistance units; electrical capacitance; thermal conductivity; neutron scattering; mechanical and chemical resistance; gamma-ray absorption; nuclear magnetic resonance.

2.2.2.9.2 Soil moisture tension: tensiometers; suction plate, pressure plate and pressure membranes; absorption by porous material; vapour pressure and freezing point.

2.2.2.10 Soil temperature, heat flow and soil properties

Different kinds of soil thermometers and thermographs; methods of measurement of heat flux, heat flux plates, methods of measuring heat capacity, conductivity and diffusivity.

2.2.2.11 Evaporation and evapotranspiration

2.2.2.11.1 Evaporation: small and large evaporation pans, porous, porcelain bodies, porous wick devices; lysimeters; exposure, maintenance, scale, observations and entries, calculations. Advantages and disadvantages of different types of pan let into the ground and exposed above the surface; factors influencing evaporation from a pan: depth of evaporating surface, rim effect, colour and size of pan, netwire cover, microclimate; comparison of different types of pan. Evaporation from a free water surface (pan) in relation to evaporation from other types of evaporimeter. Estimating evaporation from empirical formulae based on Dalton's Law; aerodynamic and energy balance approaches; eddy correlation and water balance techniques.

2.2.2.11.2 Evapotranspiration: lysimeters: types and application. Various types of atmometer and evaporation pan. Micrometeorological methods: aerodynamic energy-balance, eddy correlation. Approaches of Thornthwaite, Penman, Blaney-Criddle, Haude, Turc, Prescott, Hedke, Lowry and Johnson, Hoffmann and others. The relation between actual and potential evaporation.

2.2.3 Agrometeorological stations and networks

Classification of stations: principal, ordinary and auxiliary; design of networks.

2.2.4 Processing of agrometeorological data

Meaning of an observation, errors of observation, observations as samples of a population, the use of statistical methods for the quality control and processing of observations; the collection, treatment, representation and storage of climatic data, the tabulation and cataloguing of climatic observations, the publication of climatic data; nomenclature of different maps used in climatology, climograms and phytoclimograms; correlation between agrometeorological and biological data; preparation of plans for statistical studies, systematic and accidental errors; machine methods. The need for simultaneous biological and meteorological measurements of comparable accuracy and validity of sample.

2.3 Micrometeorology, microclimatology and topoclimatology

2.3.1 Definition and scope of micrometeorology, micro- and topoclimatology

2.3.2 Heat budget at the Earth's surface

Incoming and outgoing radiation types; net radiation. Heat flux in the soil; soil temperature (see 2.4.1). Heat transfer in the lower air layers: free convection, turbulence. Latent heat flux (see 2.4.3).

2.3.3 Temperature, humidity and wind relations near the ground surface

2.3.3.1 Variations in air temperature; temperature profiles (day and night).

2.3.3.2 Humidity fluctuations; wet and dry type moisture distribution profiles.

2.3.3.3 Wind structure near the ground: laminar and turbulent flow; wind profiles; effect of wind on microclimate, air pollution and dispersal of spores and seeds.

2.3.4 The influence of the ground surface on the microclimate

2.3.4.1 Type, colour and structure of the soil, microclimatic soil cover and cultural practices.

2.3.4.2 The influence of soil moisture and soil freezing on the air layer near the ground.

2.3.4.3 The microclimate above water surfaces: pools, lakes, rivers, sea.

2.3.4.4 The influence of snow cover and ice on soil- and microclimate.

2.3.4.5 The microclimate in the boundary zone between different types of soil surface.

2.3.5 The influence of plant cover (crops) on micrometeorology and microclimatology

2.3.5.1 The heat budget of plants.

2.3.5.2 Radiation penetration and exchange within a low plant cover (crop) and within a tall plant cover (forest).

2.3.5.3 Air temperature and humidity within a plant cover.

2.3.5.4 Evapotranspiration within a plant cover; the leaf area index.

2.3.5.5 Dew, rainfall-interception, leaf-wetness within agricultural crops and forests.

2.3.5.6 The influence of forests on the climate of the surrounding area.

2.3.6 The influence of topography on the microclimate

2.3.6.1 The radiation budget of different slopes.

2.3.6.2 The influence of topography on day- and night-time temperature profiles, on temperature distribution, cold air drainage, frost hollows, etc.

2.3.6.3 The influence of topography on air humidity.

2.3.6.4 The influence of topography on wind speed and wind direction.

2.3.6.5 Local winds: down- and up-slope winds, down- and up-valley winds.

2.3.6.6 The influence of topography on soil temperature and soil moisture.

2.3.6.7 The influence of topography on rainfall.

2.3.7 Instrumentation and methods of observation for micrometeorological and microclimatological measurements (see section 2.2.2)

2.3.8 Methods of evaluating and presenting micro- and topoclimatological data

2.3.8.1 The use of statistics in microclimatology.

2.3.8.2 Methods for estimating long-range macroclimatological possibilities from short-term microclimatic measurements.

2.3.8.3 Representation of microclimatological results: diagrams, large-scale maps, etc.

2.3.9 Importance for agriculture of the air layer near the ground

2.3.9.1 Influence of the variation in and the distribution of radiation temperature, humidity, and wind profiles on plants, animals, insects and plant diseases. (Instruction; details to follow in 2.7.)

2.3.9.2 Influence of the microclimate on soil management practices, plant disease control (spraying, dusting), irrigation, combined-harvesting, etc.

2.3.10 Modification of the microclimatological environment

2.3.10.1 The modification of the climate within plant covers (crops) by planting, manuring, cultivation, etc.

2.3.10.2 The influence of shading, mulching, glass screens, walls, changing the colour of the soil or screens, and irrigation on the heat and water budget of plant covers and on the whole microclimate.

2.4 Soil climate

2.4.1 Soil temperature

2.4.1.1 Heat exchange at the soil surface

The soil heat flux as part of the energy budget; factors affecting the soil heat flux; sharing of heat between air and soil.

2.4.1.2 Heat conduction in the soil

The classical theory of heat conduction in solids; transfer of heat by movement of water and water vapour within a soil.

2.4.1.3 Thermal properties of soils, their variation and measurement

Heat capacity; conductivity; diffusivity.

2.4.1.4 Soil temperature variations

Diurnal and annual cycles at the surface and other depths; theory of periodic temperature variations; equations for calculation of temperature at any depth and time given certain boundary conditions; Fourier analysis of soil temperatures; non-periodic variations of soil temperature; application of Laplace transforms to soil temperature studies; sinusoidal temperature variations in natural layered soils.

2.4.1.5 Factors influencing soil temperature

Source and amount of heat; the energy balance; latitude, slope of land, distribution of land and water; soil colour, albedo in different parts of the spectrum; thermal properties of soil; soil moisture, evaporation and condensation; vegetative cover, snow cover; frost penetration.

2.4.1.6 Modification of soil temperature by cultural practices

Shading; mulching, changing colour of surface; irrigation and drainage; tillage; glass and plastic covers.

2.4.1.7 Influence of soil temperature on agricultural production

Influence of soil temperature on plant growth; germination and seedling emergence, sprouting of bulbs and tubers, growth of roots and shoots, effect on nutrient uptake. Interactions between soil and air temperatures on plant growth, crop quality; extreme soil temperatures and plant injury, plant diseases, extent, thickness and duration of snow cover, alternate freezing and thawing, soil heaving, moisture movement. Influence of soil temperature on activity of micro-organisms: distribution, growth and numbers; decomposition of organic matter; ammonification and nitrification; soil aggregation. Influence of soil temperature on insect life.

2.4.2 Soil moisture

2.4.2.1 Soil moisture content

Percentage by weight, percentage by volume, bulk density, hygroscopic water, capillary water, gravitational water.

2.4.2.2 Soil moisture-energy relations

Total potential in the soil system, the capillary potential, free energy, soil moisture potential pF and log-tension, relation between soil moisture content and soil moisture tension for different types of soil.

2.4.2.3 The movement of water in the soil

Movement of liquid water in saturated and unsaturated soils; movement of water vapour; movement in relation to plant-root extraction.

2.4.2.4 The influence of soil moisture content and potential on plant growth

Field capacity; wilting point; available soil moisture in relation to germination, transpiration and vegetative growth, maturation and yield of crops; critical growth periods; farming systems in relation to available soil moisture; the importance of water conservation for agricultural purposes.

2.4.3 Evaporation and evapotranspiration

2.4.3.1 Evaporation

The theory of evaporation; factors influencing the evaporation from a free water surface: radiation, temperature of the water surface, wind movement, air pressure, quality of water. Evaporation losses and the future of evaporation pans in agricultural research.

2.4.3.2 Evapotranspiration

The individual and combined influence of soil, plant and climatic factors on evapotranspiration.

2.4.3.3 Irrigation scheduling

2.4.3.3.1 Effect of soil, crops and climatic factors on irrigation needs.

2.4.3.3.2 Application of estimating evapotranspiration on the scheduling of irrigation.

2.5 The hydrological cycle in agriculture

2.5.1 The hydrological cycle

Rainfall and its interception by plants, crops and forests, runoff, infiltration, moisture retention of the soil, percolation, evaporation, evapotranspiration; its importance in agriculture; effects of agricultural practices on component parts of the cycle.

2.5.1.1 Soil moisture budgets; use of models appropriate to alternative husbandry practices, fallow periods, irrigation etc.

2.5.2 Droughts (long period)

Definition; possible causes; frequency; principal drought-afflicted areas and countries; long-term planning against drought; the possibility of cloud stimulation.

2.5.3 Excess of precipitation

2.5.3.1 Runoff, soil erosion and their control.

2.5.3.2 Floods: causes, frequency, prediction and control.

2.5.3.3 Snow melt.

2.5.4 Hail

Occurrence and frequency of hail storms; extent and pattern of hail damage; meteorological conditions favourable for the formation of hail; types of hailstones; artificial prevention of hail, statistical evaluation of experimental results; experimental procedure for growing artifical hailstones; radar studies in connexion with hailstorms.

2.5.5 Dew

The theory of dew formation; conditions favouring the formation of dew; the importance of dew for plants, plant diseases, animals and insects.

2.5.6 Soil moisture (see 2.4.2)

2.5.7 Evaporation and evapotranspiration (see 2.4.3)

2.6 Biological measurements (phenology)

2.6.1 Introduction

Definition, history, the need for phenological data and studies for agriculture.

2.6.2 Phenological observations for agriculture

2.6.2.1 Phenological observations of plants. Plants (native and cultivated) and their growth phases: time of germination, emergence, shooting, flowering, ripening, harvesting, defoliation, etc.

2.6.2.2 Measurement of plant-growth (phenometry). Leaf-size, length of stalks, thickness of tubers, etc.

2.6.2.3 Observations of birds, insects and diseases: migration, appearance, outbreak of diseases and epidemics.

2.6.2.4 Collection of data. Networks and stations, phenological gardens.

2.6.3 Evaluating of phenological data

2.6.3.1 Examination of data and possible errors.

2.6.3.2 Statistical methods: mean values, parallelism of different phases, duration of growing periods, etc.

2.6.3.3 Representation of data, diagrams, maps, profiles, etc.

2.6.4 Research

2.6.4.1 Research on observations made at one station (time sequence, etc.).

2.6.4.2 Research on observations at different stations (area analysis, etc.).

2.6.4.3 Periodicity and prediction.

2.6.4.4 Influence of weather, climate, topography, soil, etc. on biological events.

2.6.5 Application to agriculture

2.6.5.1 Delimitation of natural growing (farming) areas.

2.6.5.2 Phenological climatology.

2.6.5.3 Management decisions, irrigation, etc.

2.6.5.4 Improvement of cultural practices.

2.6.5.5 Forecasting of biological phenomena for crop production, plant disease-control and seasonal operations (see 2.11.3).

2.6.5.6 Advising for agricultural trade and commerce (export, import, etc.) (see 2.11.1).

2.7 Weather and climate in relation to plants and crops, animal production, insects and plant diseases

2.7.1 Plants and crops

2.7.1.1 Growth and development in plants: annual life cycle; phasic divisions of the plant; measurement of growth and development.

2.7.1.2 Effect of weather factors on the growth and development of plants and on quality and quantity.

2.7.1.2.1 Air temperature: plant temperatures; cardinal temperatures; optimal temperature ranges; temperature efficiency; temperature and transpiration; thermoperiodism; low temperatures: stimulating effects, cold injury, the hardiness problem, frost damage and frost resistance (see 2.9); insufficient cold during dormant period, delayed foliation of deciduous fruit trees; high temperature injury: sun-scald; importance of temperatures over the whole growing season and during critical growth periods; heat unit systems.

2.7.1.2.2 Intensity, duration and quality of light: effects on photosynthesis; optimum leaf area index; photoperiodism; transpiration; germination; reproduction; growth forms; physiological characteristics.

2.7.1.2.3 Atmospheric humidity; optimum humidity ranges for growth; effects on transpiration and plant diseases.

2.7.1.2.4 Wind: effects on: transpiration; desiccation; dwarfing; deformation; anatomical modifications; pollination; dissemination.

2.7.1.2.5 Soil temperature: (see 2.4.1.7).

2.7.1.2.6 Soil moisture (see 2.4.2.4).

2.7.1.3 The climatic requirements of crops, e.g. corn, wheat, small grains, sorghum, cotton, tobacco, sugar cane, sugar beet, fruit trees (tropical, subtropical and deciduous), vines, berries, vegetables, etc., the adaptation of plant to the environment; use of climographs in introducing new varieties. Plant-climate relationships and the use of phenology in ascertaining the thermal and photothermal requirements of crops, e.g. wheat, barley, rye.

2.7.1.4 Well-established relations between weather and climatic factors, severally or jointly, on the growth and quantitative yield of crops; critical periods for growth and production; significance of such studies for crop forecasting (see 2.11.3).

2.7.1.5 Influence of weather and climate over the growing season upon the quality of the crop, the length of its storage life or storage behaviour, e.g. deciduous fruit.

2.7.2 Animal production

2.7.2.1 Thermal balance: the necessity of maintaining a thermal balance in animals between heat production or gain from the environment and heat lost to the environment; the thermal balance equation.

2.7.2.2 The direct effects of weather and climate upon livestock production: the effects of solar radiation, temperature (high or low), atmospheric humidity, length of day and altitude, severally or jointly, upon respiration, pulse rate and body temperature; loss of water from the body; growth rate and body weight; reproduction; grazing habits and food intake; mild production; sunburn, skin cancers and photosensitive disorders.

2.7.2.3 The indirect effects of weather and climate upon livestock production: effects of weather on the gross yield and quality of feed supply and hence on rate of growth and on milk production; regional effects of seasonal weather and climate upon the type, spread and intensity of parasitic diseases, influence of weather on diseases caused by viruses, bacteria, protozoa, helminths and metabolic disorders; use of meteorological data for forecasting disease outbreaks (see 2.11.3); effects of weather on the storing and handling of animal products.

2.7.2.4 Acclimatization

Comfort zone for different breeds of animals; differences between species and breeds in their ability to withstand extreme climatic conditions; symptoms of inadaptability.

Adaptation to new environments: heat stress in relation to acclimatization; the Bergman law; physiological adaptation.

Use of climographs in evaluating the possibility of adaptation to new environments.

Overcoming climatic disadvantages by selecting and breeding.

2.7.2.5 The climatic aspects of livestock production in super-humid, humid, sub-humid, semi-arid and desert areas

2.7.2.6 Protection against cold and excessive radiation

Loss of stock in cold weather; the need for shelter: shade trees, artificial shelters and air conditioned barns (see 2.12.3); protection against excessive radiation: ameliorating thermal stress on animals by such methods as shading, sprinklers, mechanical air circulation, wallows and air conditioning; the effect of heated barns on milk and butterfat production; effect of shade on rate of growth.

2.7.2.7 Research: instrumentation

Direct observations in the field; psychrometric chambers; thermometers, thermocouples and thermistors for measuring rectal and skin temperatures; instruments for measuring the cooling power of the air, e.g. the katathermometer, frigorimeter, coolmeter, hot-wire anemometer; climatic indices for indicating heating or cooling power of the air.

2.7.3 Insects

2.7.3.1 Effects of weather factors on insect life and activity

The effect of radiation, temperature, atmospheric humidity, light, air movement, atmospheric pressure and electricity on such physiological processes and insect activities as respiration, development, duration of life, reproduction, stridulation, movement, flight and dispersion; effect of daily and seasonal changes in weather on the daily rhythm and seasonal cycles of insects.

2.7.3.2 Climate and insect distribution

Vital limits for insect life; climatic factors assisting and limiting the dispersal of insects; the importance of ecoclimates and microclimates in the distribution of insects; use of climographs in studying insect distribution; acclimatization.

2.7.3.3 Effect of climate on abundance

Direct effects of temperature, precipitation, wind, atmospheric pressure, thunderstorms or a combination of these factors in insect abundance; influence of climate upon the number of generations; indirect effects of climate on food and natural enemies; climate in relation to control, course and periodicity of outbreaks.

2.7.3.4 Forecasting

(See 2.11.3)

2.7.3.5 Bioclimatic studies on insect pests: procedure

Field studies: physiological life-history; climatic observations (normal and microclimatic); analysis of meteorological data; quantitative studies on insect abundance; correlation of climatic data with quantitative data.

Artificial climatic studies: Controlled climatic chambers, biotron.

2.7.4 Plant diseases

2.7.4.1 Weather factors conducive to infection

Temperature: optimum temperatures for infection; effect of temperature on incubation period; effect of high temperatures on sporulations of fungus pathogens and longevity of spores; temperature in relation to disease proneness of the host.

Humidity: the importance of free water (rain, fog, dew, water of guttation, snow cover and duration of surface wetness for spore germination and infection; the effect of high atmospheric humidity on sporulations of fungus pathogens and on longevity of spores.

Light: injuries to infection process by light.

Wind: dissemination of fungus spores and bacteria by wind; windbreaks in relation to infection.

Electrostatic charge: possible effects of electrostatic charges carried by fungus spores on epidemiology of disease.

2.7.4.2 Effects of temperature and moisture on the seasonal and geographic distribution of diseases

2.7.4.3 Methods and techniques

Correlations between natural or induced diseases and meteorological records or of synthesized environments; the need for microclimatic observations; artificial climates: greenhouses and phytotrons.

2.7.4.4 Disease forecasting

(See 2.11.3)

2.7.4.5 Treatment of a few typical plant diseases

For example: apple scab, caused by fungus Venturia inaequalis; potato late blight, a fungus disease caused by Phytopthora infestans; wheat stem rust caused by a fungus Puccinia graminis tritici.
(Diseases appropriate to the area concerned to be selected.)

2.8 Agroclimatic classifications

2.8.1 Existing classifications:

The need for agroclimatic classifications; existing classifications (for details, see section 7.3 of the Guide to Agricultural Meteorological Practices. WMO - No. 134. TP. 61); limitations of the present classifications.

2.8.2 Factors to be considered in agroclimatic classifications

Elements important to the vegetative growth of plants, e.g. water balance, temperature, duration of frost-free period, duration of sunshine;

Elements important to the development of successive phases in plant life, such as, for example, day length; annual temperature variation; daily temperature range, both in the warm and cold seasons; duration of frost-free period; duration of rainy and dry seasons.

2.9 Frost and protection against frost

2.9.1 Economic phases of frost protection; the extent of damage to crops by frost during the growing season and by freezing temperatures during the winter; the possibility of minimizing frost damage to plants.

2.9.2 Physical processes involved:

2.9.2.1 Causes of frost.

2.9.2.2 Radiation and advective frosts

Seasonal occurrence; related weather patterns; donor areas and the flow and pooling of cold air; temperature inversions; effect of soil conditions, ground cover and cultural practices on frost intensity.

2.9.3 Physiological processes involved:

Theories on mechanism of frost injury; frost hardiness; critical temperatures for plants and crops.

2.9.4 Frost protection methods

2.9.4.1 Diminution of frost damage by changing the microclimate by temporary or permanent measures.

2.9.4.2 Passive methods

Location of growing areas; choice of growing season; time of planting and sowing; selection and breeding; cultivation practices: soil management, plant management, use of growth regulators.

2.9.4.3 Active methods

Pre-irrigation, coverings, smoke and artificial fogs; wind machines; sprinkler irrigation; orchard and soil heating; a combination of two or more of these methods.

2.9.4.4 Frost combating

Operational procedure; applicable frost protection methods; critical temperatures and when to protect; coverage, economic phases of frost protection: type of crop to be protected; installation, overhead, operation, fuel storage costs; comparative costs of frost protection methods.

2.9.5 Advisory services to farmers

Climatological temperature surveys and microclimatological variations; advice to farmers on choice of crop species and varieties, choice of growing areas, choice of planting dates, source regions of cold air, frost risks, average date of last frost in spring and first frost in fall, length of growing season, probability of frost occurrence, frequency and severity of frosts, establishment of microclimatic frost stations.

Local frost-fighting organizations.

2.9.6 Frost forecasts and warnings

(See 2.11.3)

2.10 Windbreaks and shelterbelts

2.10.1 Introduction

Definition of windbreaks and shelterbelts; the need for protecting soil, soil-water, plants and animals, or for improving the soil-, micro- and crop-climates by windbreaks or shelterbelts.

2.10.2 Effects of shelterbelts on the micro- and soil climate

2.10.2.1 The modification of the microclimate, especially wind speeds, by using shelterbelts and windbreaks.

2.10.2.2 On airflow:

The effect of width, shape and density of shelterbelts on airflow when wind is blowing perpendicular, oblique or parallel to the belt; the effectiveness of different systems (parallel rows or networks of belts) on air flow; wind conditions at the ends of and at gaps in shelterbelts; the effect of surface roughness and thermal stratification; the effect of topography.

2.10.2.3 On heat balance:

On radiation; air and soil temperature.

2.10.2.4 On water balance:

On atmospheric humidity; dew-fall and fog precipitation; precipitation; snow-cover; evapotranspiration; soil moisture.

2.10.3 Counteracting wind and water erosion by shelterbelts

2.10.4 Effects of shelterbelts

On crops, livestock, fauna and buildings.

2.10.5 Climatological information required in the regional planning of shelterbelts and windbreaks.

2.10.6 Meteorological, agricultural and biological observations in long-term trials on the effects of shelterbelts and windbreaks.

2.10.7 Selecting, planting, care and maintenance of shelterbelts.

2.11 Information, forecasts and warnings for agriculture and forestry

2.11.1 Agrometeorological information

Bulletins (pentad, weekly, decadal, monthly)

Organization of information service: code, network, communications, sending in reports, synoptic method of working out bulletins, issue and distribution.

2.11.2 Weather forecasts

2.11.2.1 General weather forecasts

Weather forecasts covering a period of time as required by agriculture (period of vegetation; ten days, a week, five days) given in simple clear wording; stress on factors particularly important for agriculture such as strong winds and cold waves, frost possibility, heavy rain, storms, droughts, etc.; daily weather forecasts on a regional scale giving a rough estimate of the essential factors, e.g. temperature, cloudiness, precipitation (seasonal and climate change forecasts).

2.11.2.2 Special weather forecasts and warnings

Weather forecasts relating to the seasonal requirements of cultivated plants, e.g. the planting and growing season, frost, plant diseases, noxious insects, spraying and dusting operations, irrigation requirements, harvest conditions, post-harvest and storage conditions, weather during transport of agricultural products, forestry operations, fire weather (including forest fire warnings), agricultural aviation, etc.

2.11.3 Agrometeorological forecasts

Local frost forecasts: formulae for predicting minimum air temperature; the importance of the "no-danger" forecast. Soil humidity forecasts. Forecasts of dates of successive phases of plants development; forecasts of yield and crop quality. Forecasts and warnings concerning livestock; disease forecasting: forecasts on relative abundance, expected periods of increase or decrease, time of peak infestation. Forecasts on the distribution, outbreaks and seasonal events of insects (pests and beneficial). Parameters used in forecasting. The most widespread methods. Issue of forecasts and warnings.

2.12 Artificial climates

2.12.1 Glasshouses, cloches, hotbeds, etc.

Ventilation; heating and cooling; illumination; soil moisture and evapotranspiration.

2.12.2 Growth cabinets, growth room, phytotron, climatron, biotron

The variation of all meteorological entities over a wide range.

2.12.3 Animal and poultry houses

Site orientation; colour; texture; construction; ventilation; heating and cooling; air composition; humidification; illumination; photoperiodicity; quality of light; air and litter moisture content; air circulation.

2.12.4 Storage rooms, clamps, pits.

ANNEX II

SYLLABUS II

Syllabus in agricultural meteorology for graduates in agricultural sciences

I. THEORETICAL COURSE

1. INTRODUCTION

1.1 The concepts weather and climate (macro-, meso- and microclimate).

1.2 The importance of weather and climate for agricultural production
(Essentially a revision subject; the extent will depend on the standard of previous instruction)

The adaptation of plants, crops and animals to the climate; the necessity of adjusting farming systems to the natural environment; critical plant-growth periods in relation to temperature and soil moisture; the importance of weather and climate data in determining the irrigation requirements of crops; climate in relation to insect pests and plant diseases; production and cultivation practices in relation to climate; climatic hazards affecting agricultural output, e.g. drought, hail, frost, strong winds, etc.

1.3 Agricultural meteorology

Definition, aims and scope; difference between meteorology and agricultural meteorology; a short history of agricultural meteorology in relation to the needs of agriculture and the development of meteorological apparatus.

1.4 National Meteorological Services and the World Meteorological Organization (WMO).

1.5 National agrometeorological organizations and the Commission for Agricultural Meteorology (CAgM).

2. THE ATMOSPHERE AND PRESSURE VARIATION

Its nature, composition and properties; air pollution, carbon dioxide; extent and structure: troposphere, stratosphere, mesosphere, ionosphere and exosphere; pressure of the atmosphere; units; variation of pressure with height; mercury barometers; the aneroid barometer; the barograph; altimeters.

Daily and seasonal variations; some effects of variations in air pressure upon animals and insects.

3. RADIATION IN THE ATMOSPHERE

Sources of heat for the atmosphere; the sun and radiant energy; the electromagnetic spectrum; Wien and Stefan-Boltzmann radiation laws; Lambert's law; the solar constant.

Seasonal and latitudinal variation in length of day. Factors influencing the amount of radiation incident upon the Earth's surface; absorption, reflection and transmission; albedo; terrestrial radiation.

o Instruments for measuring incoming solar radiation; pyrheliometers of Angström and Abbot (silver disk) for measuring direct radiation; the Eppley and Moll-Gorczynski actinometers and the Robitzch bimetallic actinograph for measuring direct and diffuse radiation.

Energy in different parts of the spectrum and its biological significance; illumination. Penetration of radiation through a crop canopy.

Radiation balance: its importance to plant and animal processes. Bright sunshine duration and its measurement, e.g. with the Campbell-Stokes, Marvin and Jordan photographic recorders.

4. METEOROLOGICAL ELEMENTS

4.1 Air temperature

Different temperature scales; representative air temperature and its measurement; thermometers and thermographs (liquid-in-glass, deformation, liquid-in-metal, electrical resistance thermometers, thermocouples, thermistors); maximum, minimum and mean air temperature; daily and seasonal variations; vertical temperature gradient; temperature inversion; isotherms. The importance of temperature in the growth of plants; frost-free growing season; vegetative period.

4.2 Atmospheric humidity

Water vapour in the atmosphere and its variation with height; importance in determining the possibility of rain, snow and hail and its role in the development of thunderstorms; importance in the growth of plants; effect on the loss of heat from the human and animal body. Absolute humidity, relative humidity, saturation deficit, dew point, specific humidity, mixing ratio, vapour pressure. Daily variation of the absolute and relative humidity, and their variation with height and latitude. Instruments for measuring humidity, absorption hygrometers; the psychrometric formula.

4.3 Condensation, precipitation and evaporation

The process of condensation in the atmosphere; its importance in the formation of fog, clouds, rain, hail, snow, frost and dew. Fog and cloud formation; a simple classification of clouds, cloud covers. Thunderstorms: formation, frequency; lightning; precautions against lightning; hail; the structure of hailstones; theories of hail formation. Precipitation; the size and rate of fall of raindrops; types of rain; seasonal variation of rainfall; the measurement of rainfall (the ordinary raingauge and continuous rainfall recorders, rate-of-rainfall recorder); snow and its measurement; statistics on extreme precipitation. The process of evaporation; factors influencing the rate of evaporation; simple formulae for calculating the rate of evaporation. Instruments for measuring evaporation. The relation between evaporation from a free water surface and evaporation from moist soil and leaf surfaces. Degrees of error inherent in measurements and in estimates from calculations.

4.4 Winds and circulation patterns

Wind and air currents; the cause of winds; direction, speed and pressure; windroses; daily and seasonal variations and variation with height. The measurement of wind direction and speed. Isobars, field of pressure, pressure gradient.

The general circulation of the atmosphere; the effect of the Earth's rotation on the flow of winds across the isobars; Buys Ballot's law. Planetary, terrestrial and continental winds. Land and sea breezes, mountain and valley winds of local importance, e.g. Föhn or Chinook, Bora, Harmattan, Mistral, Sirocco. The tropical cyclone or hurricane; tornadoes; water-spouts; duststorms. The extra-tropical cyclone: its origin. The polar-front theory; air masses; weather along the cold and warm fronts; the occluded front. Anticyclonic or high pressure systems and associated weather.

5. WEATHER AND CLIMATE

Pressure systems and other factors such as latitude, altitude and sea currents affecting the country's weather and climate. Discussion of climate of the country concerned; the distribution and intensity of rainfall and its efficiency for agricultural production; temperature: seasonal variation and extremes of temperature affecting agricultural output; lack of sufficient sunshine; excessive evaporation. Climatic trends and changes.

6. MICROCLIMATOLOGY

The importance of the air layer near the ground to agriculture. Heat exchange at the ground surface; the flow of heat into the ground; soil temperature and its effect on plant growth and soil activity; factors affecting soil temperature; instruments for measuring soil temperature. Air temperature, humidity and wind variations in the micro-layer; the importance of these variations for plants, animals insects and plant diseases. Influence of type and soil condition, plant cover and topography on the microclimate. Influence of the microclimate on the formation and occurrence of frost; diminishing frost damage by altering the microclimate. The influence of shelterbelts and framing systems on the microclimate.

7. CLIMATIC HAZARDS ADVERSELY AFFECTING AGRICULTURAL OUTPUT

7.1 Insufficient soil moisture during critical growth periods

The hydrological cycle: rainfall, infiltration, moisture retention capacity of the soil, percolation, runoff, evaporation, transpiration and evapotranspiration. The importance of soil moisture for plant growth. Soil moisture measurements, soil moisture conservation; farming systems in relation to available soil moisture in the arid, semi-arid, sub-humid and humid regions. Irrigation and supplementary irrigation; water conservation. Application of climatic data in scheduling irrigation; estimating actual and potential evapotranspiration.

7.2 Droughts (long period)

Definition; possible causes; frequency; principal drought-afflicted areas; long-term planning against drought; the possibility of cloud stimulation.

7.3 Hail

Frequency of hail storms; hail damage and its prevention.

7.4 Frost and frost combating

Extent of frost damage; intensity and frequency of damaging frosts; sensitivity of plants to low temperatures; radiation and advective frosts; methods for predicting frost conditions; methods of preventing frost damage at the time of planting; ways of diminishing frost damage, e.g. cloches, chemical smokes, orchard heating sprinkler irrigation, wind machines.

7.5 Strong winds

The importance of windbreaks and shelterbelts; the detrimental effects of strong winds on plants, animals and the soil. The effects of windbreaks upon the environment. Different types of windbreak; the advantages and disadvantages of shelterbelts. Trees and types of shelterbelt suitable for local conditions.

8. ECOLOGY OF CROPS, ANIMALS AND INSECTS

Well-established relations between meteorological and climatic factors, severally and jointly, on the growth and yield of crops and animals; effect of weather and climate on insect pests and plant diseases. Climatic requirements of crops, fruit trees and animals with respect to heat, light and moisture. Adaptation of plants and animals to the climate.

9. AGROCLIMATIC STATIONS

Classification (principal, ordinary and auxiliary); networks; observations; equipment; relevant biological observations.

The processing, tabulation and interpretation of agrometeorological data; statistical and mathematical methods of analyses.

10. CROP FORECASTS

Crop forecasting techniques and examples of forecasting time of emergence of seed, vegetative growth periods, flowering, maturity and yield of crops.

11. INVESTIGATIONS AND RESEARCH

Development of crop-weather relationships; use of semi-empirical models.

12. SPECIAL WEATHER FORECASTS FOR AGRICULTURE

Elementary forecasting technique, interpretation of daily weather charts; frost danger warning for crop protection; veld and forest fire warnings; planting and harvesting weather forecast; insect and disease forecast; spraying and dusting weather forecast; livestock weather forecast; post-harvest and storage forecast; agricultural aviation forecast; warm and cold spells; wet and dry spells; severe weather.

II. PRACTICAL COURSE

1. PRACTICAL WORK ON METEOROLOGICAL INSTRUMENTS AND METHODS OF OBSERVATION

1.1 Pressure

Units and relation between different units; reduction of pressure to other levels; mercury barometers; method of observation; correction of barometer readings to standard conditions: index error, gravity correction, temperature correction; exposure, transportation and installation of the mercury barometer; the barograph: care and maintenance, evaluation of the records; the aneroid barometer.

1.2 Surface wind

Units; relation between different speed units; determination of true north, the compass points; estimation of wind speed, the Beaufort scale; different types of anemometer and anemograph; evaluation of the records; exposure of wind equipment.

1.3 Temperature

Fahrenheit, Celsius and absolute temperature scales; liquid-in-glass thermometers: the ordinary thermometer, the maximum thermometer, the minimum thermometer, the soil thermometer, reading a thermometer; electrical thermometers: the resistance thermometer, thermocouples, the thermistor, auxiliary electrical equipment; thermographs: the bimetallic type, the Bourdon-tube type, the mercury-in-steel type, evaluation of the records; thermometer and thermograph exposure, general requirements in order to obtain representative air temperature, thermometer screens, artificial ventilation, exposure of soil thermometers and grass minimum thermometers; the importance of calibration certificates; possible sources of defects in thermometers and the various procedures to rectify them.

1.4 Duration of sunshine

Sunshine recorders; exposure and installation of sunshine recorders; evaluation of the records.

1.5 Atmospheric humidity

Units and methods; simple psychrometer without artificial ventilation, the sling psychrometer, the Assmann type psychrometer, exposure and observational procedure, care of the wet bulb, operation of wet bulb below freezing, sources of error in psychrometry, the psychrometric formula, tables and slide-rules; hair hygrographs: general requirements, exposure, management and transportation, accuracy and sources of errors, washing the hairs, evaluation of the records; dew-point and frost-point hygrometers; electrical absorption-type hygrometers.

1.6 Precipitation

Units; errors and accuracy of reading; the ordinary and totalizer raingauges; rainfall recorders; rainfall intensity recorders; evaluation of the records; exposure of raingauge: general rules, influence of strong and gusty winds; rainfall measurement on slopes; snow measurements; dew and leaf-wetness measurements.

1.7 Evaporation

The main classes of evaporimeter: large evaporation tanks, small evaporation tanks, porous bodies, porous paper wick devices; exposure, maintenance, scale, observations and entries, calculations.

1.8 Soil moisture

Units of measurement, visual observation, gravimetric method, obtaining percentage moisture by volume, tensiometers, electrical methods, thermal methods, neutron scattering method, gamma ray absorption method.

1.9 Radiation

Units, types of instrument; estimates from simple data.

ANNEX II

2. PRACTICAL WORK BASED ON THE THEORETICAL COURSE

2.1 Climatological analysis: processing of observation data preparatory to ultimate use and interpretation, e.g. averages, normals, frequencies, standard deviation, etc. Study of the climate of the region or continent concerned: statistical analysis of representative climatic elements, the drawing of isopleths, etc.

2.2 Calculation of derived parameters, e.g. evaporation, radiation, climatic indices; testing of "models".

2.3 A study of the variation of temperature, humidity and wind in the micro-layer. A microclimatological study of a suitable area.

2.4 A study of the influence of different windbreaks and shelterbelts on the microclimate.

2.5 A study of frost-protection methods.

2.6 A study of meteorological aids to irrigation practice.

2.7 Analysis and interpretation of elementary synoptic charts; preparation of routine forecasts; examples of special weather forecasts for agriculture.

2.8 Practical crop-forecasting, including yields, quality, sowing and harvest dates.

2.9 A monograph by each student on the application of agrometeorology to his or her particular field of study in agricultural science.

ANNEX III

SYLLABUS III

Syllabus for technical assistants

in agricultural meteorology

1. BASIC KNOWLEDGE REQUIREMENTS

1.1 Mathematics and physics

The standard of mathematics and physics required will be that of the secondary-school level.

1.2 Astronomy and physical geography

A good knowledge of the universe, the solar system, Sun, Moon and Earth.

1.3 Biological sciences

An elementary knowledge of appropriate biological sciences.

1.4 General meteorology

1.4.1 The nature of the atmosphere

Composition and properties; atmospheric pollution; extent and structure: the troposphere, the stratosphere, the mesosphere, the ionosphere, the exosphere.

1.4.2 Pressure

Definition; Toricelli's experiments; the mercury barometer and its corrections; isobars; pressure variation with altitude.

1.4.3 Winds and circulation patterns

Wind and air currents, the cause of winds; direction, speed; daily and seasonal variation; the general circulation: effect of Earth's rotation, cyclones and anticyclones, Buys Ballot's law, the tropical cyclone, the monsoon, local winds, land and sea breezes, katabatic and anabatic winds, the Föhn wind, the tornado.

1.4.4 Radiation

The nature of radiation, the electromagnetic spectrum; basic definitions; the elementary radiation laws; the solar constant; attenuation of solar radiation by the atmosphere; geographical, annual and diurnal distribution of solar radiation; terrestrial radiation; net radiation.

1.4.5 Temperature

Different temperature scales; representative air temperature and its measurement; diurnal and seasonal variation; vertical temperature gradient, temperature

inversions; isotherms; the importance of temperature in the growth of plants, frost-free growing season, vegetative period.

1.4.6 Atmospheric humidity

Water vapour in the atmosphere and its variation with height; definitions of dew point, relative humidity, vapour pressure deficit, absolute humidity, specific humidity, mixing ratio and vapour pressure; the psychrometric formula; diurnal and seasonal variation of atmospheric humidity; importance of atmospheric humidity in the growth of plants.

1.4.7 Condensation, precipitation and evaporation

The process of condensation in the atmosphere, its importance in the formation of fog, clouds, rain, hail, snow, hoar frost and dew; the physics of precipitation: the ice crystal process, the gravitational coalescence process, size and rate of fall of raindrops; thunderstorms: classification, the Byers-Braham thunderstorm model, hail, thunderstorm electricity; the process of evaporation factors influencing the rate of evaporation.

1.4.8 Thermodynamics of the atmosphere and dynamical meteorology

The meteorological thermodynamic system; the variables of state, the gas laws; the equation of state; virtual temperature; pressure reduction to other levels; the adiabatic process, the dry adiabatic lapse rate, the saturation adiabatic lapse rate; stability and instability; the forces of gravity, the pressure gradient force, Coriolis force, centrifugal force; horizontal frictionless flow: the geostrophic wind, the gradient wind, the cyclostrophic wind; the effect of friction on wind: the diurnal variation of wind and variation of wind with height.

1.4.9 Synoptic meteorology

The synoptic method; the observation network; codes; the station model; synoptic charts; air masses: definition, source regions, movement, classification, general characteristics of air masses; fronts: warm front, cold front, associated weather; pressure systems and their synoptic significance: the anticyclone, the extra-tropical cyclone, the trough of low pressure, the ridge of high pressure, the col; elementary forecasting technique; typical synoptic charts of the region or continent concerned.

1.5 Climatology

The concept of climate; the influence of large-scale geographical factors such as ocean currents and the distribution of land masses and seas on climate; the principal climatic elements; definition of the normals of climatic elements; climatic seasons, their variability; basic principles of climate classification and global study of world climate; a more detailed study of the climate of the region or continent concerned; the utilization of climograms and phytoclimograms; application of climatology to various human activities with special reference to agriculture.

2. AGRICULTURAL METEOROLOGY

2.1 Scope of agricultural meteorology

Definition, aims; the relationship between weather, climate and agriculture: soils, plants, farm animals, diseases and pests of crops and animals, farm buildings and equipment, artificial modifications of the meteorological and hydrological

régime; a short history of agricultural meteorology in relation to the needs of agriculture and the development of meteorological apparatus; national Meteorological Services; the World Meteorological Organization (WMO), the Commission for Agricultural Meteorology (CAgM).

2.2 Agrometeorological observations

2.2.1 Meteorological observations

Units, accuracy, importance; exposure of instruments and general rules for the observation of pressure, air temperature, atmospheric humidity, wind, sunshine and radiation, precipitation, evaporation, soil temperature, soil moisture content and soil moisture tension; interpretation and analysis of autographic charts; cloud classification: genera, species and varieties, the synoptic classification; significant cloud, cloud cover, estimation of cloud base; horizontal visibility; existing weather conditions; state of the ground (dew etc.).

2.2.2 Biological observations

Observations on native plants and on cultivated crops and trees, farm animals, diseases, insect pests, and general activities on the land.

2.3 Agrometeorological instruments

The choice of a site for an instrument enclosure; a detailed study of the procedures for installation, maintenance, checking and calibration of the following instruments:

2.3.1 Pressure

The mercury barometer: method of observation, exposure, transportation and installation; correction of barometer readings to standard conditions: index error, gravity correction, temperature correction; the barograph; the aneroid barometer.

2.3.2 Surface wind

The pressure plate anemometer; cup and propeller anemometers: the hand anemometer, the totalizing anemometer, contact and generator type of anemometer and anemograph; the pressure-tube anemograph; the hot-wire anemometer; etc.

2.3.3 Radiation

The exposure and maintenance of the major instruments for measuring short-wave, long-wave, and net radiation, spectral distribution; the measurement of illumination; evaluation of the records.

2.3.4 Duration of sunshine

Sunshine recorders; exposure and installation, maintenance; evaluation of records.

2.3.5 Temperature

Liquid-in-glass thermometers: ordinary thermometers, maximum thermometers, minimum thermometers, soil thermometers, reading a thermometer; electrical thermometers: resistance thermometers, thermocouples, thermistors, auxiliary electrical equipment; thermographs: the bimetallic type, the Bourdon-tube type, the mercury-in-steel type; thermometer and thermograph exposure: general requirements in order to obtain representative air temperature, thermometer screens, artificial ventilation, exposure of soil thermometers and grass minimum thermometers; the importance

of calibration certificates; possible sources of defects in thermometers and the various procedures to rectify them.

2.3.6 Atmospheric humidity

Psychrometers: simple psychrometer without artificial ventilation, the sling psychrometer, the Assmann-type psychrometer, exposure and observational procedure, care of the wet bulb, operation of wet bulb below freezing, sources of error in psychrometry, the psychrometric formula; tables and slide-rules; hair hygrographs: general requirements, exposure, maintenance and transportation, accuracy and sources of errors, washing the hairs; dew-point and frost-point hygrometers; electrical absorption-type hygrometers.

2.3.7 Precipitation

The ordinary and totalizing raingauges; rainfall recorders; rainfall intensity recorders; snow measurements: depth and density.

2.3.8 Dew and leaf wetness

The Duvdevani dew block, Leick plates, weighing type of apparatus; leafwetness recorders.

2.3.9 Evaporation and evapotranspiration

The main classes of evaporimeter: large evaporation tanks, small evaporation tanks, porous porcelain bodies, porous paper wick devices: lysimeters; exposure, maintenance, scale, observations and entries, calculation.

2.3.10 Soil moisture content and soil moisture tension

Tensiometers; the gravimetric determination of soil moisture content; resistance of porous blocks; the neutron moisture meter.

2.4 Processing of agrometeorological data

2.4.1 Statistics

Meaning of an observation, errors of observation, observations as samples of a population; quality control and processing of observations; climatological data: collection, treatment, storage, cataloguing, publication.

2.4.2 Statistical methods

Frequency distributions: relative frequency, cumulative frequency, histogram; statistical parameters: mode, median, quartiles, percentiles, arithmetic mean, standard deviation, variance, weighted and adjusted means, means from grouped data; significance tests: Student's t-test, the X^2 test; regression: significance of a regression coefficient; correlation, significance of a correlation coefficient, analysis of variance.

2.5 Microclimatology

Importance of the air layer near the ground for agriculture; variations of leaf and air temperature, humidity and wind in the microlayer; influence of topography, soil type, soil condition and vegetation on the microclimate.

2.6 Soil temperature

Flow of heat in the soil; diurnal and seasonal variation of soil temperature at different depths; factors affecting soil temperature; the importance of soil temperature for plant growth.

2.7 Soil moisture

The hydrological cycle; the importance of soil moisture for plant growth.

2.8 Weather hazards adversely affecting agricultural output

2.8.1 Droughts

Definition; frequency; long-term planning against drought; the possibility of cloud stimulation.

2.8.2 Hail

Frequency of hail storms; hail damage and its prevention.

2.8.3 Frost

Extent of frost damage; sensitivity of plants to low temperatures; radiation and advective frosts; taking account of frost in agricultural planning; ways of diminishing frost damage; artificial methods of combating frost damage -- e.g. orchard heating, sprinkler irrigation.

2.8.4 Strong winds

The importance of windbreaks and shelterbelts; the detrimental effects of strong winds on plants, animals and the soil; the effects of windbreaks upon the environment; different types of windbreak; the advantages and disadvantages of shelterbelts; trees and types of shelterbelt suitable for local conditions.

2.9 Practical applications

Practical application of meteorological and climatological data of plants, crops, animals, insects and plant diseases.

2.10 Agrometeorological research

A discussion on research problems applicable to the region or country concerned.

2.11 Practical training

The theorical course must be supplemented by an intense training in outdoor practical work, especially concerned with the maintenance of instruments and the taking of observations.

ANNEX IV

Syllabus for teaching agricultural meteorology at advanced schools of agriculture, horticulture and forestry

I. LECTURES TO BE INCLUDED IN THE PROGRAMMES

A. Agriculture and horticulture schools

1. Meteorology and its importance in a country's economy
(especially in farming, gardening and forestry)

2. The terrestrial atmosphere
- 2.1 Composition
- 2.2 Vertical structure
- 2.3 Certain physical properties

3. Atmospheric pressure
- 3.1 Measurement of pressure; mercury and aneroid barometers, barographs
- 3.2 Pressure changes with altitude; determination of altitude
- 3.3 Pressure variations

4. Nature of radiation
- 4.1 Solar radiation: physical properties of radiation; direct solar radiation; diffuse radiation; radiation transmission and absorption
- 4.2 Long-wave radiation; effective radiation
- 4.3 Albedo
- 4.4 Radiation measurements
- 4.5 Duration of sunshine
- 4.6 Significance of radiant energy in plant life: greenhouse effect; photosynthesis, growth, photoperiodism, phototropism

5. Air and soil temperature
- 5.1 Air temperature measurements
- 5.2 Daily and annual variation of air temperature
- 5.3 Vertical air temperature distribution; temperature inversions
- 5.4 Horizontal distribution of air temperature; charts of isotherms at sea-level and at surface

5.5 Soil temperature measurements

5.6 Daily and annual variation of soil temperature

5.7 Factors influencing soil temperature

5.8 Influence of air and soil temperature upon plants and the processes of growth, photosynthesis and respiration

5.9 Resistance of plants to high and low temperature

5.10 Frost and frost protection

6. Water vapour in the atmosphere and soil moisture

6.1 Atmospheric humidity: definitions, significant values, measurements

6.2 Evaporation: evaporation process; measurement of evaporation from water and land surfaces; transpiration and evapotranspiration

6.3 Soil moisture: kinds of soil water; agrohydrological soil properties; soil moisture measurements

6.4 Soil water balance

7. Condensation and precipitation

7.1 Conditions favourable for water vapour condensation

7.2 Dew and hoar frost

7.3 Fog

7.4 Cloud

7.5 Precipitation: formation; types; measurement

7.6 Role of water in plant life: a general idea of water economy of plants

7.7 Significance of snow cover for soil and plants

8. Motion in the atmosphere

8.1 Causes and kinds of winds

8.2 Isobars, pressure gradient

8.3 Coriolis force, effect of friction, centrifugal action

8.4 Winds connected with cyclonic and anticyclonic circulation

8.5 Wind in the free atmosphere; in lower layers; local winds

8.6 Wind structure and measurement

8.7 General circulation

8.8 Wind as a factor in plant habitats; need for shelterbelts

9. Synoptic meteorology (basic knowledge)

9.1 Air masses and fronts

9.2 Lows: theory of low formation; associated weather

9.3 Highs: associated weather

9.4 Weather service: weather maps and analysis, weather forecasting

10. Climatology

10.1 General notions of climate

10.2 Factors influencing climate

10.3 Major climatic zones of the Earth

10.4 Climate of the country concerned: general remarks on particular elements

11. Biological measurements (phenology)

11.1 Importance of phenology for meteorology and agriculture.

11.2 Phenological observations

11.3 Phenological seasons

11.4 Phenological cartography

NOTE: Stress to be laid on observations dealing with practical agriculture.

12. Agrometeorological stations

Organization, equipment, measurements, observations, information provided

13. Examples of the application to practical agriculture of agrometeorological knowledge and data

B. Forestry schools

Syllabus as under A (Agriculture and horticulture schools), with the following amendments:

Add "4.7 Penetration of light into forests"

Add "5.11 Air temperature within the forest"

Replace 6.1 by the following text:

"6.1 Atmospheric humidity: characteristic magnitudes; measurement; atmospheric humidity within forests"

Replace 7.5 by the following text:

"7.5 Precipitation: formation; types; measurement; rainfall measurements at the floor of the forest"

Add "8.9 Wind speed within the forest"

Add "10.5 Influence of the forest on the macroclimate, climate of the clearing in forests"

Add "11.5 Phenological investigations within forests"

Replace 12 by the following text:

"12. Forest meteorology services"

II. PRACTICAL EXERCISES

During the lectures under Section I above, instruments are to be shown to the students. The purpose of the practical exercises dealt with in the present section is that during these exercises, students should acquire knowledge of how to operate the following instruments and how to evaluate the records.

1. Pressure

Mercury barometers, corrections; aneroid barometers; barograph

2. Radiation

Basic instruments for measurements of solar radiation and sunshine duration

3. Temperature

3.1 Standard meteorological thermometers: ordinary, maximum, minimum; reading, corrections, recording, computing mean diurnal air temperature, plotting isotherms; thermographs.

3.2 Soil thermometers; reading, corrections, recording; graphic representation

4. Atmospheric humidity and soil moisture

Psychrometers and psychrometric tables, hair hygrometer, hygrographs. Evaporimeters; lysimeters. Determining soil moisture by the gravimetric and visual methods

5. Precipitation

Measurement of precipitation by gauges and recorders; snow measurements. Plotting isohyets

6. Wind

Observations of wind direction and speed; pressure plate anemometer and cup anemometer; anemographs

7. Climatology

Climatological observations. Preparation of climatological reports

8. Biological measurements (phenology)

Plotting phenological charts (see Guide to Agricultural Practices, Section 7.1.2: Cartographic presentation)

9. Visits

Visit to agrometeorological research stations, sites of field experiments, and to the national Meteorological Service

ANNEX V

LIST OF TEXTBOOKS AND PUBLISHED LECTURE NOTES OR MONOGRAPHS PERTAINING TO INSTRUCTION IN AGRICULTURAL METEOROLOGY

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* CONRAD, V. and POLLAK, L. W., 1950 -- Methods in climatology. 2nd ed. Harvard University Press, Cambridge, Mass. 459 pp.

CRITCHFIELD, H. J., 1960 -- General climatology. Prentice-Hall, Inc., New York. 465 pp.

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